Economic feasibility tool for fish farming – case study on the Danish model fish farm in Finnish production environment

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Abstract
This report introduces the use of the Excel tool published by Aquabest-project for evaluating economic feasibility of fish farming. The present report is a case study on profitability and production costs of using the Danish model fish farm concept in the Finnish production environment (including market, cost structure, climate). For such conditions, an isolated building is needed for temperature control, but we also calculated a case where the fish tanks are not placed in a building, which will reduce the annual fish production.

Production cost was to 4.48 €/kg gutted 500 gr rainbow trout. Feed cost was the highest cost factor with 31% of the cost. Second highest costs were investment deprecation with capital costs, together 21% of the production cost. Therefore efficient use of the investment by temperature control and especially investment need for isolated building become important cost factors in colder climate. Electricity cost that is generally highlighted as one of the disadvantages of RAS farming, is not among the main cost factors in the Danish Model farm concept.

Finally, the regional market price is of utmost importance since the production cost will be higher than the current price at the highly competed European markets. We assumed a producer price 4.50 €/kg in the Finnish market.

Keywords
RAS, Fish farming, Investment, Profitability, Model, Rainbow trout

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Additional information

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1. Introduction

1.1. Economic feasibility assessment

Environmental policy goals to decrease nutrient emissions have led to stagnated fish production in the Baltic Sea Region (BSR). Fish products are imported into BSR to meet the demand, while environmental consequences are externalized to those regions that produce the fish consumed in the BSR. To switch this trend, BSR aquaculture must adopt new sustainable practices and technologies, and introduce regulation that encourages the development and use of abatement measures.

New environmentally sustainable technologies are emerging in aquaculture and the opportunity to increase production without additional nutrient discharges makes recirculation aquaculture systems (RAS) an interesting option. In addition to reduced discharges, RAS allows better control of production conditions especially temperature and the technology drastically reduces the need for intake water which enables these farms to be placed in unconventional locations.

There are high expectations among decision makers on adopting RAS farming. However, markets are global and highly competed, and new technologies need to be economically competitive to be viable in the long term. RAS systems require higher investments and there are other additional cost items which may increase production costs. Therefore, assessment of economic feasibility by comparing production costs and market price is thus of utmost importance within the BSR, including Finland (Nielsen et al. 2014).

This report illustrates the use of the Excel spreadsheet published by Aquabest-project, to evaluate economic feasibility of RAS farming (Kankainen 2014). As the example, we use Danish model fish farm concept applied in Finnish production environment (market, cost structure, climate) to assess the opportunities by meeting the nutrient discharge reduction targets by RAS farming. The production equipment and tank investment costs were evaluated according to Danish cost level. Other cost factors, such as isolated building and variable costs such us energy, work and fingerlings, were estimated according to Finnish cost level. The technology used in these farms is briefly described below.

1.2. Danish model fish farms

In traditional freshwater or marine production systems, the water flows through the system only once. In RAS farms, 95-99% of the water is directed back to the production system after used in fish tanks. To maintain proper water quality before the water is reused, mechanical and biological water treatment is needed. The main emphasis to maintain proper conditions for fish welfare and viable business is to, firstly, remove particle substances quickly by sedimentation and filtration, secondly, to remove carbon dioxide by aeration and/or stripping, thirdly, to add oxygen, and finally, to transform toxic ammonia to less harmful nitrate by biological filtration. Further information on RAS technology is available at e.g., Jokumsen and Svendsen (2010), Dalsgaard et al. (2013), Pedersen and Jokumsen (2014), and Suhr (2014).

The Danish model fish farm concept was developed to reduce nutrient discharges due to stringent environmental regulation (Jokumsen and Svendsen 2010). The first generation of these farms (model trout farm type 1) was actually not recirculation aquaculture, but merely used mechanical filtration and re-used a part of the water after aeration and in some cases oxygenation. The second generation (model trout farm type 2) introduced the biological filtration, and can thus be classified as RAS farms.

However, many engineering changes to these farms have emerged, and the current farms (model trout farm type 3) are more intensive. Model farms mostly use raceways, but lately, octagonal or rounds tanks have become more common in new type 3 farms. Model farm water treatment technology can also be placed indoors for especially juvenile production (Figures 1-4).

Model fish farms are not the most intensive RAS farms. Model fish farms typically use 3000-4000 liters of water per kg feed in comparison to 100-1000 liters per kg in more intensive RAS farms. Model fish farms do not heat or cool the water, nor have used UV or ozone in water treatment. So far, these farms have been placed outdoors whereas globally most RAS farms are located indoors, even in isolated buildings. However, type 3 farms may in future be located in buildings in Denmark. Typical for the Danish concept is also the use of constructed wetlands to decrease nutrient discharges further. These characteristics make model trout farms a rather unique.

An additional characteristic of model farms is low water pumping heights and, thus, moderate energy consumption than has been typically considered high in RAS. Lower pumping heights (typically 0.5-1.0 meters) decrease energy consumption, which can be as low as 1.0-2.0 kWh per kg growth. Low pumping heights are achieved by several engineering decisions, especially biofilter design, low-head aeration and oxygenation systems, and by modern pump technology.

The waste from a model farm is similar but smaller in quantity to the waste from a traditional farm, and will mainly consist of organic matter (measured as BOD, biological oxygen demand), nitrogen (N) and phosphorus (P). Table 1 shows a comparison in discharges between traditional Danish farms and a Danish model 3 farm. The specific discharge (kg/t fish produced) of N, P, and organic matter from the model farms amounted to 64, 38, and 6%, respectively, of the corresponding estimated discharge from traditional Danish freshwater trout farms (Svendsen et al., 2008). Without the wetlands, phosphorus load (the main target of regulation in Finland) would be 1.3 kg per tn produced fish based on the data by Svendsen et al. (2008).

Table 1. Comparison of discharges of Nitrogen (N), Phosphorus (P) and organic matter (BOD) from model trout farms (type 3) and traditional trout farms in Denmark during the monitoring project.

Kg/tn produced fish	Traditional farms in 2006	Model farm type 3 2006-2007	Model farms, % of traditional farms
Total nitrogen	31.2	20.0	64
Total phosphorus	2.9	1.1	38
BOD	93.6	5.6	6

1.3. Model farm concept in colder climate conditions

Climate and access to ground water sources makes model farm concept ideal for the Danish conditions. Within the Baltic Sea region, similar conditions can be expected in southern Sweden, Germany and Poland. However towards the north, the concept will face the challenge of colder winter temperatures and consequent decrease in fish growth and annual production. The important question now becomes if farms should invest in water temperature control consisting of isolated building and even heat pumps and relating temperature control systems. By these investments, winter growth can be increased and also peaks of high temperature during the summer can be avoided, but with additional capital and variable costs.

1.4. Profitability case study

In the present economic feasibility study we analyze production costs of portion size (500 gram) rainbow trout production in the northern BSR by using Finnish temperatures in the case study, and then do sensitivity analyses by varying the most important parameters likely to be encountered in practical business cases. Of special interest will be the influence of water temperature and consequent annual production. Furthermore, the economic feasibility of investing in isolated building to control the temperature will be analyzed.

We have designed a cost structure for a farm producing 500 gram rainbow trout, which is a rather common product for the European markets. It is also currently the major product for Danish model trout farms. The investment, which stems from the knowledge on several farming projects in Denmark, would be able to produce 500-600 tons of fish under typical Danish model fish farm temperature conditions. The production equipment and tank investment costs were evaluated according to Danish cost level. Other cost factors, such as isolated building and variable costs such us energy, work and fingerlings, were estimated according to Finnish cost level.

The production costs are compared to assumed producer price of 500 gram rainbow trout in Finland. In Finnish domestic market neither portion size rainbow trout nor filet of portion size fish are common products. Thus market price or producer price was not available. Based on substitute product prices and discussion with the processing and retail sectors, producer price of 4.5 €/kg could be possible in Finnish market for a small volume of domestic production of fresh (nor frozen), high quality production. In comparison, the producer price for larger trout has varied in the past few years between 3.20 and 5.50 €/kg.

Figure 1. Abild model trout farm in Denmark. Photo: Peder Nielsen.

Figure 2. Løjstrup model trout farm in Denmark. Photo: Peder Nielsen.

Figure 3. Model trout farm type 3 with round concrete tanks. Photo: Peder Nielsen.

Figure 4. Skade indoor model trout farm in Denmark. Photo: Peder Nielsen.

2. Cost and productivity factor assumptions

2.1. Investment and other fixed costs

2.1.1. Investments and the annual production

The farm consists of 24 pcs of octagonal /or round concrete tanks, each of 135 m^3 in volume. The large number of tanks allows constant delivery of fish to markets, and is also beneficial for the disease control since several separate water treatment units are used.

Fish are put into the systems at an average size of approx. 20 g and are feed until they reach a size of 500 g. Farm has four water treatment systems for six tanks each, with common water treatment unit consisting of a drum filter, submerged bed filter, degassing and oxygenation units. The above mentioned production system with fish tanks and water treatment systems would require 3.600 m^2 building.

The total tank volume of 3240 m^3 is adequate for 500-600 tn production in typical for Danish farm using groundwater. With a typical annually turnover between 2.5-3 for fish up to 500 gr and a stocking density up to approx. 70 kg/m3 the total standing stock (average biomass) will be approx. 227 tn. For the present case study, we estimated annual production by using temperature profile from a lake in the Middle-Finland, and assumed based on experience at RAS farms, that pumps and other devices increase the temperature within the isolated building by two degrees. Annual growth was estimated using TGC-model (e.g., Jobling 2003), and found to be 430 tons. This annual production is the value used in further profitability calculations. Without the isolated building, ambient lake temperature would provide annual growth of 370 tons, whereas additional investments in heat pumps and additional energy would allow annual production similar to the Danish conditions. These issues are discussed further in the sensitivity calculations (Chapter 3.2 and 3.3).

Farm should locate near the water resource that generally increases the value of estate. The “Constructions” include earthwork, water canals/pipes, concrete tanks as well as feed and pump warehouses; “Covered isolated building” price estimate (500€/m^2) is for Finnish conditions with high construction costs due to earthwork for cold climate, thick insulation and snow load for winter times. The building price includes also the basic electricity and air-conditioning devices. “Equipment” includes technical equipment and items such as biofilters and drum filters aeration, oxygenation and pumps. Back-up power, alarm system, electricity installation and fish and feed handling devices (e.g. separation, harvesting, gutting equipment) are estimated to “Other production equipment”. Transport includes lift trucks, bulk trucks and tractors for managing the feed and harvest operations and transfers. Also “Monitoring and management” of the construction work and “Technical consultancy and supervision” of fish farm are calculated separately. The work related to other cost item is included in investment prices. For estates and constructions we used 10 year depreciation time. For technical equipment we used 5 years write-off period. Constructed wetland is not included in this investment.

Public investment subsidy in for such investment has been lately 30% through European Fisheries Funds (EFF, in the future European Maritime and Fisheries Fund EMFF). However some communes may support these kind of projects even with larger subsidies or discounts, for example for purchasing the estates. All cost factors include VAT.

Table 2. Investment costs and deprecation by item

Investment costs		Investment total value €	3 710 000	Investment weighted average depreciation	8,8
Production estates		Investment initial value	200 000	Deprecation years	10
Production constructions		Investment initial value	900 000	Deprecation years	10
Farming equipment		Investment initial value	400 000	Deprecation years	5
Other production equipment		Investment initial value	200 000	Deprecation years	5
Transport		Investment initial value	100 000	Deprecation years	5
Monitoring and Management		Investment initial value	50 000	Deprecation years	3
Other	Furniture	Investment initial value	10 000	Deprecation years	5
Other	Isolated production building	Investment initial value	1 800 000	Deprecation years	10
Other	Consultancy and supervision	Investment initial value	50 000	Deprecation years	5

Investment subsidy	Investment value with subsidy €	2 597 000
% of the investment total value		30 %

Figure 5. Technical details on the water treatment systems at a model trout farm. Photos: Peder Nielsen.

2.1.2. Permanent personnel

According to experience from Denmark it should be possible to produce approximately 250 – 300 tn annually with one person year, however manager personnel is also needed for running operations. The larger the farm, the less personnel are needed per produced kilo fish.

In this feasibility study it is assumed that personnel costs consist of entrepreneur who participates daily fish farm operations and two operational staff. RAS farms should have personnel on standby 24/7 in case of production risks, such us electricity or water quality problems. Salary overhead rate of

30% cover obligatory insurance, pension, holiday pay-reserve, social security payment and taxes paid by employer. In addition to permanent personnel, gutting of the fish needs extra employees. That is estimated into variable personnel costs.

Table 3. Fixed personnel cost factors

Fixed personel costs	Person-years total	3	Average month person costs	3333
Number of staff	Person-years	2	Average month salary staff €	3000
Number of manager personnel	Person-years	1	Average month salary managers €	4000
Salary overhead rate	Share of the salary	30 %	Annual person costs	156 000

Figure 6. Preparing to grade fish at a model trout farm. Photo: Jouni Vielma.

2.1.3. Other costs with fixed character

Fixed costs means cost factors that will not directly change when production volume changes. Other fixed costs herein consist of miscellaneous cost factors listed in Table 3. The more specific descriptions of each fixed cost item can be found at red info triangles in the model (Kankainen 2014). In practice many of these cost factors may turn out to be much higher, or, in some occasions some cost factors, such as marketing is not needed at all. Infrastructure, vehicles and equipment maintenance costs increase in time and generally become significant cost factor at the end of the investment lifetime. The electricity costs estimated does not cover the electricity needed in production but includes heating and air-conditioning of the buildings, and technical devices for the gutted fish. All cost factors include VAT.

Table 4. Annual fixed costs

Other fixed costs		Annual value estimate	70 000
Rents		Annual value	5 000
Maintenance		Annual value	20 000
Production lisences and monitoring		Annual value	5 000
Book keeping and financial administration		Annual value	5 000
Marketing		Annual value	5 000
Fixed electricity		Annual value	10 000
Travel		Annual value	5 000
Research and development expenses		Annual value	5 000
Insurance		Annual value	5 000
Other	Logistic (road) fee	Annual value	5 000
Other		Annual value	
Other		Annual value	

2.2. Variable costs

Feed is usually the major variable cost factor (Table 5). Feeds for smaller fish are more expensive, but feeds for larger fish form bulk of the feed usage. Also FCR (Feed conversion ratio) changes with fish size. However these details are not included in the present model. Instead, average feed price and FCR is used.

The price of fingerlings becomes relevant factor for profitability especially in the production of table size fish when fish are sold small. The larger the fish are farmed, the less significant becomes the fingerling purchasing cost, because less fingerlings are needed for producing the same tonnage. We estimated the price of 15 €/kg for 20 gram vaccinated fingerling.

Other variable costs consist of fish insurance, electricity and transport. Also oxygenation, medical treatments and waste water treatment costs are important cost factors in RAS farming. We assumed the cost of 0.10 euros per kWh for the electricity and electricity consumption is assumed to be 2.0 kWh per kg fish growth. The modern Danish low-head model farms can be designed to use even down to 1.0 kWh per kg, but we wanted to be more conservative with the estimation. All cost factors include VAT.

2.3. Production efficacy parameters

Bio-economical productivity factors, such us growth, mortality and feed efficiency influence the efficiency of production and thereby the need for cost items introduced above (Kankainen et al 2011). Production cycle length also influences the effect of certain cost items.

The average harvest size of 500 gram was chosen because it is common European market size for rainbow trout and also produced in Danish model fish farms. In our example, at 500 g fish are gutted, although they can also be transferred to sea cage production or grown to traditional market size of over 2 kg in RAS. To calculate costs for that kind of production, gutting investments and variable labour costs can be deleted and “Gutting yield” is 100%.

Mortality varies between years, fish populations and production environments. Sometimes diseases or realisation of production risks may cause loss of a complete production batch. Normal yearly mortality is around 2-3% of individuals; however we used 10% mortality to include unexpected higher losses. To avoid total monetary lost and bankruptcy, insurance is included as variable costs in the feasibility calculation.

Table 5. Volume dependent company variable costs

Variable cost factors		Targeted by:	€	Annual total variable cost €	1 112 310
				Annual total variable cost €/kg	2,87
Feed cost		average €/kg feed	1,4	546 616	1,41
Fingerling cost	20	average €/kg	15	286 667	0,74
Roe cost		average €/kg roe			0,00
				Other annual variable cost €	279 027
				Other variable cost €/kg	0,72
Volume depended investment		€/gutted fish	0	0	
Personnel		€/gutted fish	0,1	38 700	
Fish insurance		€/gutted fish	0,2	77 400	
Vaccination		€/fish	0	0	
Medicines		€/gutted fish	0,02	7 740	
Fuel		€/gutted fish	0,02	7 740	
Electricity		€/gutted fish	0,2	77 400	
Oxygen		€/gutted fish	0,01	3 870	
Transport		€/gutted fish	0,05	19 350	
Washing water		€/gutted fish	0,001	387	
Waste water		€/gutted fish	0,01	3 870	
Ice		€/gutted fish	0,01	3 870	
Sludge treatment chemicals			0,05	19 350	
pH-control chemicals			0,05	19 350	
Other		€/gutted fish	0	0	
Other		€/gutted fish	0	0	
Other		€/piece	0	0	

Table 6. Production cycle, volume and bioeconomic productivity factors

Fingerling purchasing	Average size of fingerling gram	20	Production volume per year, kg	430 000
Growth	Estimated average final weight	500	Growth, x times the initial weight	25
Mortality	Total mortality %	10 %	Number of fingerlings	955 556
Harvest yield	Gutting yield %	90 %	Sales volume, kg	387 000
Feed efficiency	Feed conversion ratio (FCR)	0,90	Feed usage, kg	390 440

2.4. Market value

Market price for the fish is of utmost importance for the profitability. In Denmark, portion size trout producer price has lately been approximately 3.5 - 3.8 €/kg including VAT (26-28 DKK/kg) (www.danskakvakultur.dk), and has faced tough competition by especially the Turkish production. In Finnish domestic market neither portion size rainbow trout nor filet of portion size fish are common products. Thus market price or producer price was not available. Based on discussion with the processing and retail sectors on subsidy products for traditional salmonids, producer price of 4.5 €/kg could be possible in Finnish market for a small volume of domestic production of fresh, high quality production. In comparison, the producer price for larger trout has varied in the past few years between 3.20 and 5.50 €/kg. It is not obvious why consumers would be willing to pay extra or even an equal price for smaller fillets of trout, in comparison to large fillet. Furthermore, typical products (cold smoked and dill-cured "gravlax") would be more expensive and less convenient to produce using small portion size fish.

3. Preliminary profitability analysis of model farm concept

3.1. Results

Production cost based on the present calculation is 4.48 €/kg gutted fish. The production costs would mean profit of 0.02 €/kg at the producer price 4.5 €/kg. In other words, on the basis of our assumptions, productions costs would be very close to the break-even price.

3.2. Sensitivity analysis

Sensitivity analyses is a useful exercise to evaluate the influence of assumptions in the profitability calculations. Profitability analysis is useful to evaluate effects of one or several simultaneously changing cost factors. For example it is possible that water treatment system functions well and allows using higher densities and thus higher annual production of fish. On the opposite, it is also possible that the farm is still on a learning curve during the first few years of the operation, and the annual production is less than anticipated. Similar differences can take place in investments, mortality and many other parameters.

For sensitivity analysis we have given realistic risk and improvement margin for cost factors to highlight which factors may have a significant effect on the profitability (Table 8).

Table 7. Profit account for 430 tn fish farm and related production cost.

Factor based profit account		€/kg
Revenue	1 741 500	4,50
Variable costs		
Feed cost	546 616	1,41
Fingerling cost	286 667	0,74
Other variable costs	278 640	0,72
Fixed costs		
Fixed personnel	179 982	0,47
Investment depreciation	295 114	0,76
Other fixed costs	70 000	0,18
Financial costs		
Capital costs	75 421	0,19
Total costs	1 732 439	4,48
Taxes	2 537	0,01
Profit	6 524	0,02

Table 8. Profitability sensitivity analysis for major cost factors. The cost estimate for business as usual is 4.48 €/kg.

Cost factor	Assumed value	Sensitivity values		Unit	New production cost		Change in production cost	
		Low end	High end		Low end	High end	Low end	High end
Growth	430 000	380 000	480 000	Kg/year	4,69	4,31	-0,21	0,17
Investment (subsidy included)	2 600 000	2 200 000	3 000 000	€	4,33	4,63	0,15	-0,15
Interest	5 %	3 %	7 %	%	4,40	4,56	0,08	-0,08
Feed conversion ratio	0,90	0,85	0,95	kg/kg	4,40	4,56	0,08	-0,08
Feed cost	1,40	1,20	1,60	€/kg	4,27	4,68	0,21	-0,20
Fingerling cost	15,00	10,00	20,00	€/kg	4,23	4,72	0,25	-0,24

Major cost savings could be achieved by lower feed or fingerling costs. Also deviation from growth expectations have major influence on probability. RAS operations tend to overestimate fish growth especially during the first years of operation, when the new farm is still on a learning curve regarding daily management routines. Our growth estimate for the investment used in this feasibility study is somewhat conservative. Higher densities and elevated water temperatures might yield higher production. On the other hand, the water treatment systems have their maximum capacity above which problems with water quality will become apparent. Lower feed costs are not easy to realize either. The trend for feed price is rather increasing than decreasing. Higher volumes for feed purchases may give scale discounts. The feeds assumed in the present calculation contain astaxanthin, whereas for some markets table size fish do not need to be pigmented. Fish are usually fed at restricted feeding ratios without feed wastage. Good water quality and careful observation of the feeding and fish stock are essential for good FCR. Savings in feed price do not necessarily translate into lower feed costs, since RAS farms are sensitive to feed quality. Fingerling could be purchased for a lower price than we have estimated, especially if they are produced within the company. Other variable cost include some specific cost factors that may change significantly from the assumed; for example electricity, oxygenation, transport, medicines and most of all insurance are such cost factors that can vary extensively. In the Baltic Sea region, EU member states can use European Maritime and Fisheries Funds to support (subsidy) investments. In the present calculation, we have assumed 30 % subsidy for the investment.

3.3. Model farm without isolated building with northern growth rate

In our example for the cold climate, isolated production building is costing as much as 0.47 € per kg, although the building is the only way to preserve the heat loss and thus produce more than in ambient tempareture. There is no proven example of using the model trout farm technology in a colder climate without isolated production building. At minimum, the water treatment systems would require a small isolated building of approximately 400 m^2 (0.2 milj. €). Without the isolated building, due to the colder ambient temperature the annual production would be some 60 tons lower than with the building conserving the heat loss from the pumps.

This operation would result in production cost of 4.26 €/kg (Table 9). The cost is 0.2 euros lower than when company invests in the isolated building to utilize the heat loss. We want to emphasize that this kind of solution has not been tested yet in colder climate. During cold winters, severe mechanical failures may occur despite isolated building for the water treatment system.

For temperature control, access to borehole or well water sources and efficient use of space at the farm become important factors influencing the production costs. All real investments in RAS in Finland rely on isolated building and simultaneous investments in full temperature control. This will allow larger production thus decreasing the share of the isolated building costs. It may well be the most economical way of utilizing model trout farm technology in colder winter than in Denmark. Building that covers the entire production area would also bring other benefits, such as better working conditions, use of more advanced feeding systems, shelter from direct sunlight (less algae growth) and protection against predators.

Table 9. Profit account with 400 m^2 isolated building investment for water treatment system. but therefore with 14 % smaller production due to colder water temperature

Factor based profit account		€/kg
Revenue	1 498 500	4,50
Variable costs		
Feed cost	470 344	1,41
Fingerling cost	246 667	0,74
Other variable costs	239 760	0,72
Fixed costs		
Fixed personnel	179 982	0,54
Investment depreciation	167 841	0,50
Other fixed costs	70 000	0,21
Financial costs		
Capital costs	42 894	0,13
Total costs	1 417 488	4,26
Taxes	22 683	0,07
Profit	58 329	0,18

3.4. Discussion and conclusions

3.4.1. On the profitability analyses model

Economic feasibility calculations are routinely used by the business sector, but the information these calculations provide on the opportunities of new technologies are also useful for decision makers and R&D community. This report serves as an example on the use of Excel spreadsheet tool produced as part of the Aquabest-project. We have extended this simple profitability analyses model to include more detailed production planning and economic performance analysis. As an example, we have combined the spreadsheet with growth modeling that also provides information on the daily use of feed, oxygen and energy for heating the water. As an example of more detailed economic evaluation, different production cycles, multispecies farming, seasonally varying fish prices and company cash flow-analyses can be combined with the present basic model.

3.4.2. Economic feasibility of producing portion size trout in colder climate of Finland

The current calculation would indicate possible economic loss even at producer price of 4.5 €/kg, a price which could be available in Finnish market. We are aware of the fact that the producer price of portion size rainbow trout is lower in Denmark and Poland. This has been especially true in recent couple of years due to imports from Turkey, a case which will be further investigated by EU during 2014. Therefore, exporting this product profitably seems not to be a realistic option either. We should also notice that the European portion size fish has not been imported to Finland even at the European price, since there appears not to be enough demand for portion size rainbow trout in Finland.

Finnish Game and Fisheries Research Institute has very recently studied the interest of the wholesale sector and processors on the locally produced table size rainbow trout. Finnish consumers have traditionally used large salmon or rainbow trout filets that are cheaper to produce, process and buy. Therefore it is not obvious why consumers would choose smaller and more expensive table size fish file instead. Also, the consumption of whole fish has decreased continuously in Finland and therefore it is not realistic to forecast large markets for gutted fish, even if the size would be more attractive than the large fish. However with some special quality characteristic and marketing, table size fish may win some markets from the bulk salmon filet products. In the Finnish markets, there is a higher demand for filet of fish over 2 kg. Therefore, it would be interesting to evaluate how competitive RAS farming, for example using the model farm technology, could be in such production. Some cost factors would decrease, such as fingerling price, whereas some cost factors would increase such as capital costs due to slower stock turnover rate of the larger, slower growing fish.

In the sensitivity analyses, single cost factors were varied but only some of them separately resulted in profitable production. However, we did not calculate cases where several cost factors are changed simultaneously. Combined effect of several cost factors such as cheaper juveniles, lower mortality, and higher annual production due to increased fish density – a possible scenario based on the information from the sector – would make the production profitable albeit on a narrow margin. However, it is also quite possible to encounter increasing building costs, delays in the start-up phase, slower growth of fish and even drastic losses due to unexpected failures in the technology, which would increase the production costs even from the estimated.

The single most important cost factor that is different between the established Danish production and our case study, is the need for isolated building. The influence of the building was as high as 0.46 €/kg fish in the present calculation. In Finland costs was evaluated to be more than 500 €/m² for isolated building. The estimations for insulated building in Denmark is around 150 €/m². This difference, together with the need to warm the water, or lower annual output without heating, become a major cause of the price difference between production in Denmark and northern BSR. Therefore, more detailed analyses on the optimal water temperature control such as alternative ways to isolate the tanks and water treatment systems, and when to heat the water, is needed. If full control of the water temperature is targeted, then heating pumps and further filtration systems are required which means additional investments and higher energy consumption. On the other hand, the investment such as the building and water treatment system could be used at the full capacity around the year.

A final but important note on the sensitivity analyses is the size of the production unit. Our example farm is smaller than several latest true investment cases, where annual production fetch to 1000 tons and more. Significant savings can be expected due to scale of economics. However, financing such investments becomes more complicated and investors outside the traditional farming sector may be needed. Such large RAS farms have not been granted licenses in Finland and the regulation practices remains to be seen. Phosphorus load of the current example, 430 ton producing farm, approximately 500 kg P, would higher than most traditional inland fish farms, although largest licenses are 1000-200 kg P per year. In the current assessment, we did not include wetlands, since their efficiency in removing nutrients in the Northern conditions is not certain. Wetland would allow higher production, if the nutrient discharge quota is the limiting factor for the production.

One option for profitable RAS business is to produce larger trout for further sea cage farming. Similar development is taking place in Norway, where larger salmon smolts for cage farming are produced in RAS than in conventional farms. The most likely scenario in the Baltic Sea cage farming is that new production will be located in harsh conditions towards the open sea. In such sites, growing season may be too short to reach the market size if regular size juveniles are used. With RAS system larger fish could be produced for the beginning of the season in the spring so that fish would reach market size before cages are towed away from the open sea before the winter. RAS farming may also be the only solution to get new licenses for smolt production on the coastal areas nearby the cage operations due to stringent environmental policies. (Kankainen et al. 2014, Kankainen and Mikalsen 2014, Vielma and Kankainen 2013).

3.4.3. On the RAS farm design

There is a continuous discussion on the best way to design a RAS farm. Currently in Denmark, there is a tendency of shifting from serial connected raceways to parallel connected raceways or tanks with circular flow. Each design has its own advantages and disadvantages and should be evaluated separately for each investment case. Below is a summary of advantages and disadvantages of different designs. In the case of colder climate where investments in the isolated building can be significant, the efficient use of space, both by the fish tanks but also by the water treatment technology, becomes a cost factor worth closer analyses.

Serial connected raceway systems	
Advantages	**Disadvantages**
• Simple construction. • Few pipes and valves reduce the pressure loss in the system. • Simple operations. • Relatively low energy consumption (1.7 – 2.2 kW/kg produced table size fish). • Low investment cost.	• Sedimentation of sludge around the system. • Attention must be kept to prevent sedimentation of sludge' in each single section. Water quality may vary within the raceway. • High risk of a complete loss of fish stock due to chain reaction. • Require fish in all section of each system at all time. • Poor oxygen and high CO_2 level can occur. • Fluctuating temperature (if outdoor). • Moderate growth rate. • Difficult to treat against diseases.

Parallel connected raceway systems	
Advantages	**Disadvantages**
• Simple construction. • Simple operations. • Very secure system. • Very low energy consumption (1.0 – 1.5 kW/kg produced table size fish). • Few pipes and valves reduce the pressure loss in the system. • Each individual raceway can be emptied and disinfected without any influence on the other raceways. • Easy to treat against diseases. • Relatively high growth rate. • Moderate investment cost.	• Attention must be kept to prevent sedimentation of sludge in channels and raceways (the risk is highest with small fish in the raceways).

Round or octagonal tanks with circular flow	
Advantages	**Disadvantages**
• Self-cleaning ability. • Very secure system. • Stabile temperature because of surface/volume ration. • Each individual tank can be emptied and disinfected without any influence on the other tanks. • Easy to treat against diseases. • Possible to achieve good oxygen condition in all tanks. • Possible to achieve low CO_2 concentration if all tanks have own aerators. • High growth rate. • Low investment cost (in Denmark due to the pre-casted concrete tanks used in agriculture).	• Relatively complicated construction. • Relatively complicated operation. • Moderate energy consumption (1.5 – 2.3 kW/kg produced table size fish). • More pipes and valves complicate the construction and result in higher pressure loss.

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